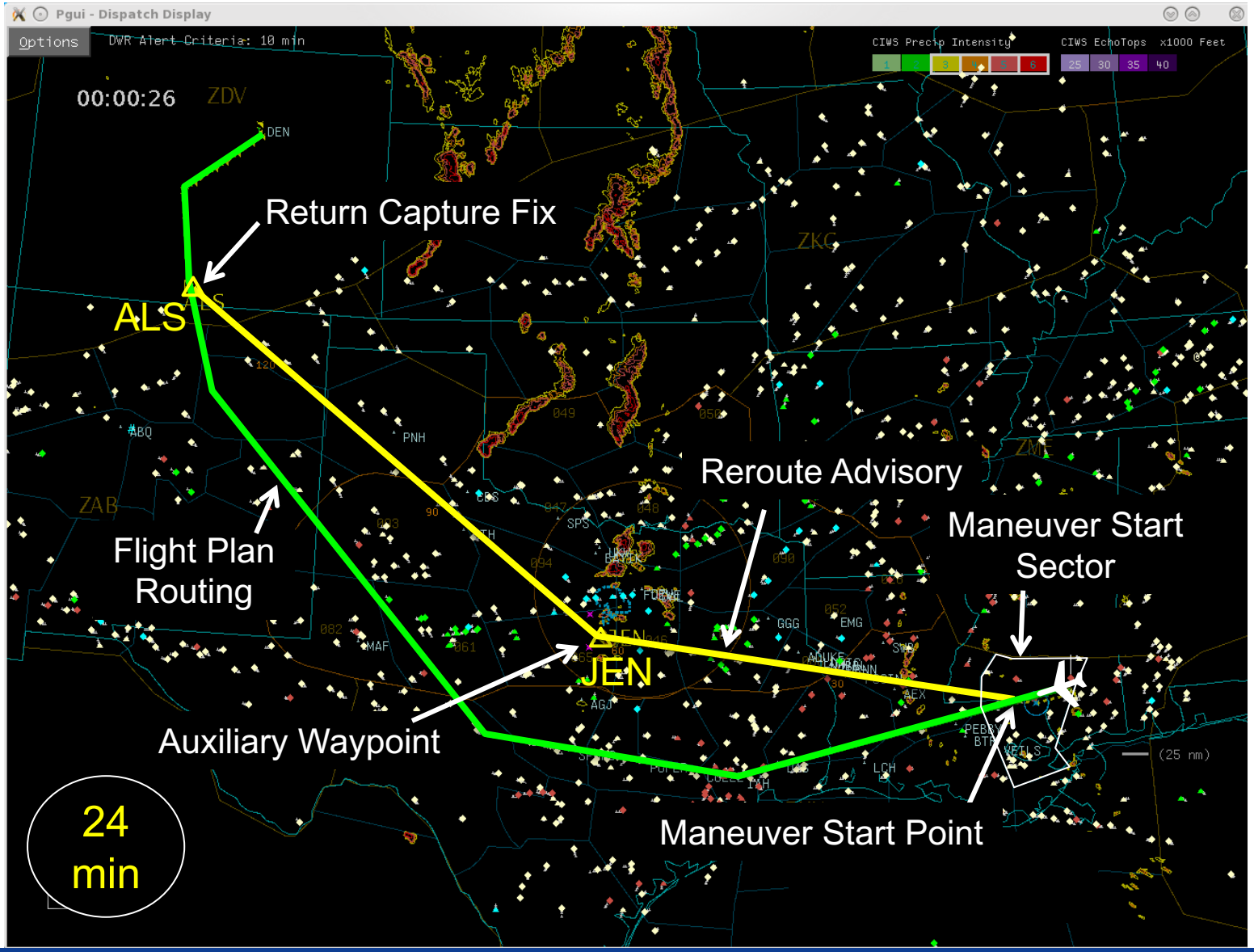
Predicting the Operational Acceptance of Route Advisories

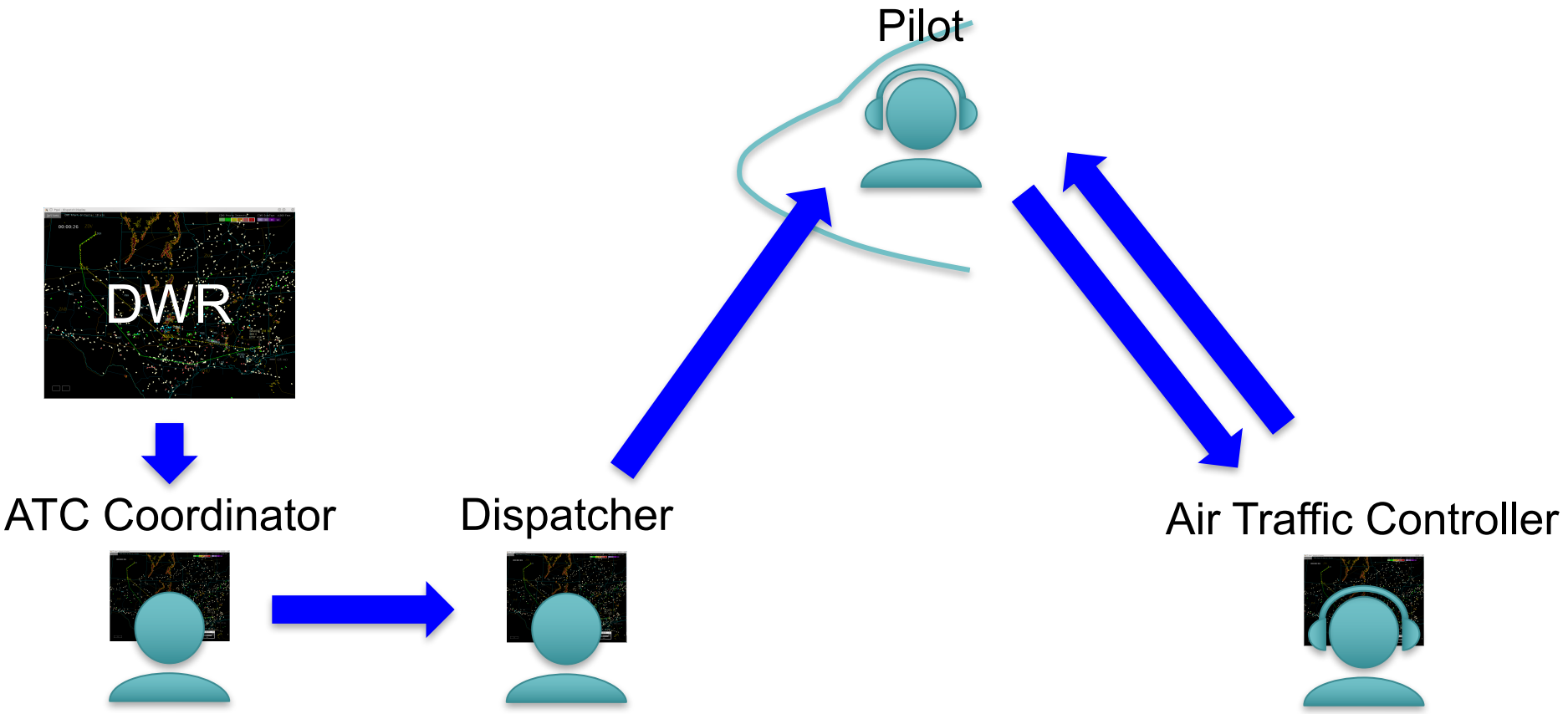
Antony Evans (Crown Consulting, Inc.)

Paul Lee (NASA Ames)

Reroute Advisories



Dynamic Weather Routes (DWR)



Motivation

Route Observed in Flight Plan Amendment Data
(Jun-Aug 2015)

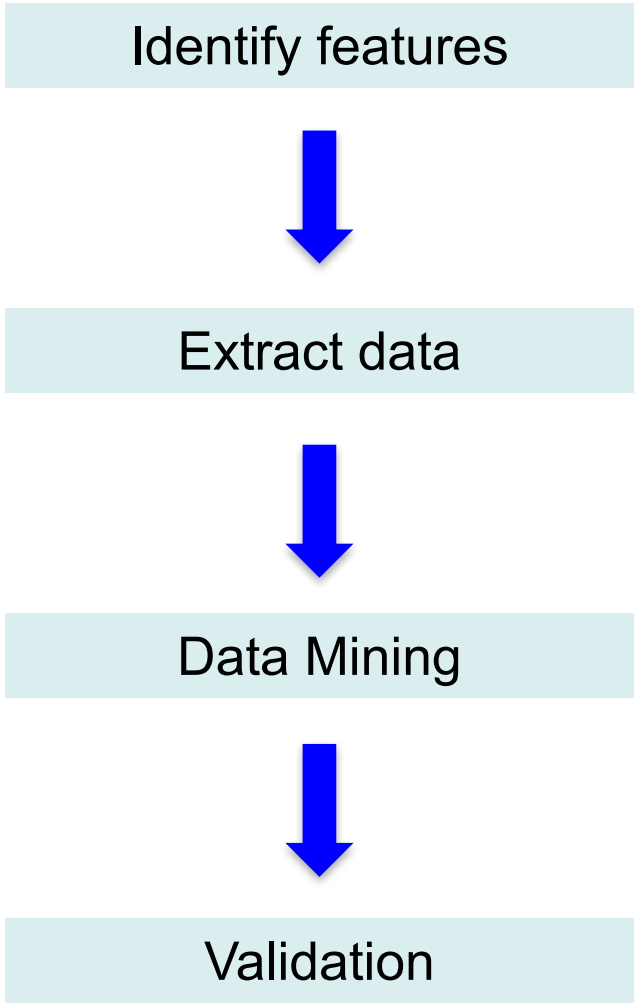
ATC Response to DWR Route Advisory (DWR trial, 2014)	True	False
Accepted	97%	3%
Rejected	69%	31%

Evans, et al. (2016)

- Historical usage required for ATC route acceptance
- Other factors also contribute to ATC acceptance

- Objective: Develop a predictor of operational acceptability for route advisories

Approach

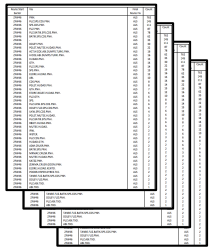


- Literature review
- Subject matter experts

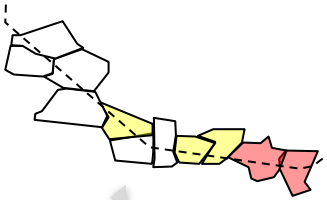
- ATC accepted routes
- ATC rejected routes

- Binary classifier

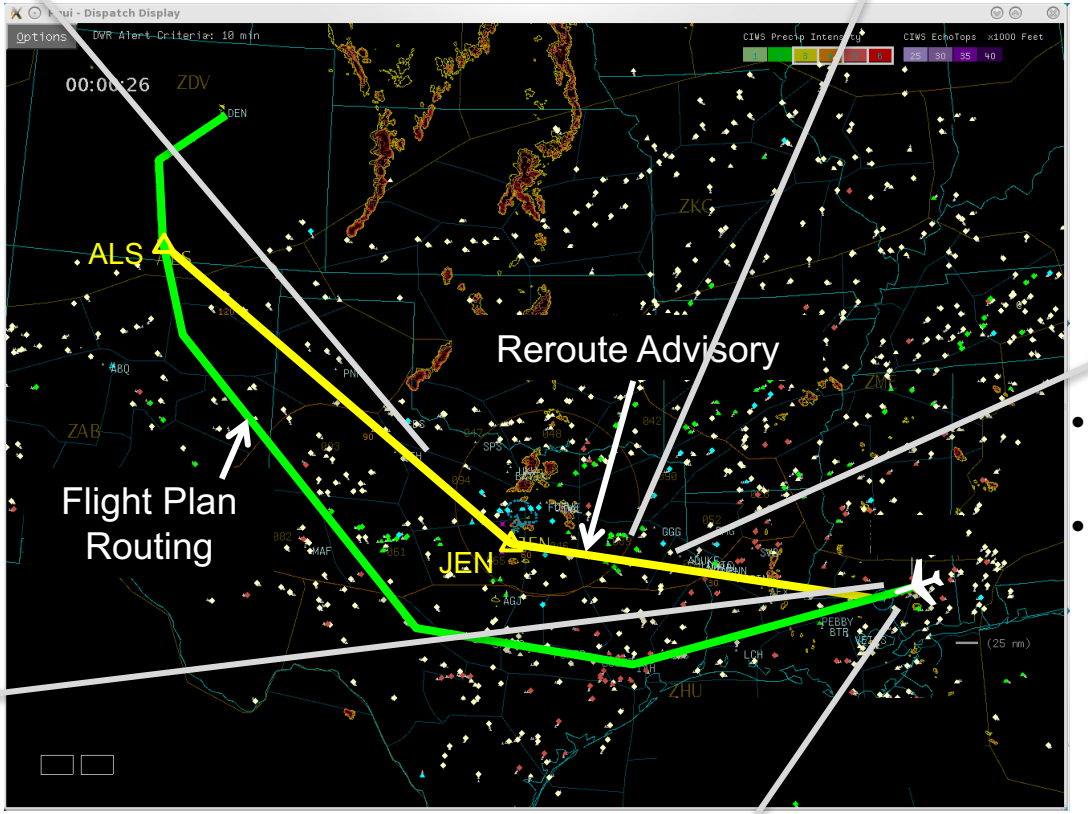
Features

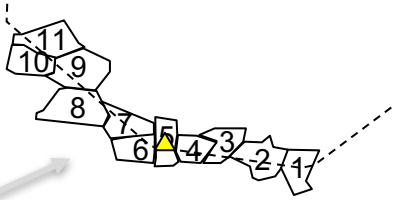


- Historical count (full route)
- Historical count (by segment)

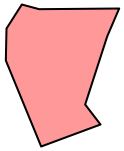


- Number sectors over capacity
- Max demand to capacity ratio

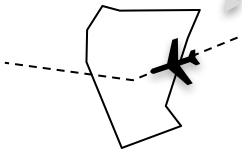




- Number downstream sectors
- Direct routing or via aux. waypoint



- Maneuver start sector demand/capacity
- Maneuver start sector over capacity



- Time to exit maneuver start sector
- Distance between maneuver start point and sector exit

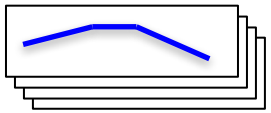
Data

Usage

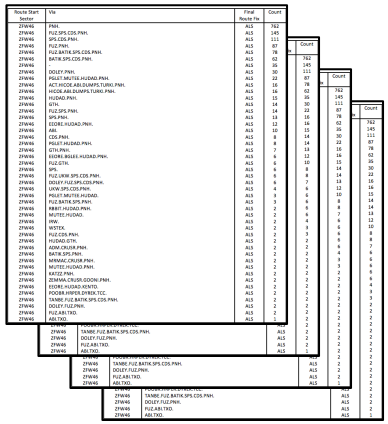
ASDI Data

June 2015 | July 2015 | August 2015

Flight Plan Amendments



Common Routing Tables



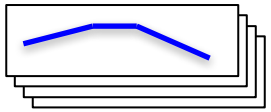
Usage

Feature Extraction

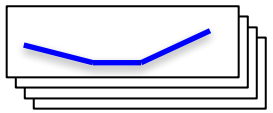
DWR Trial Data (ZFW and adjacent Centers)

May 2014 | June 2014 | July 2014 | August 2014 | September 2014

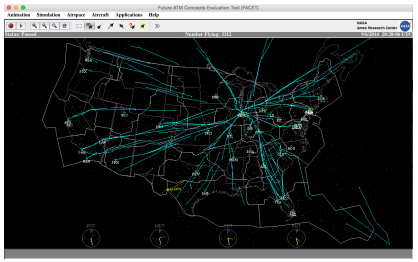
DWR Advisories



Flight Plan Amendments

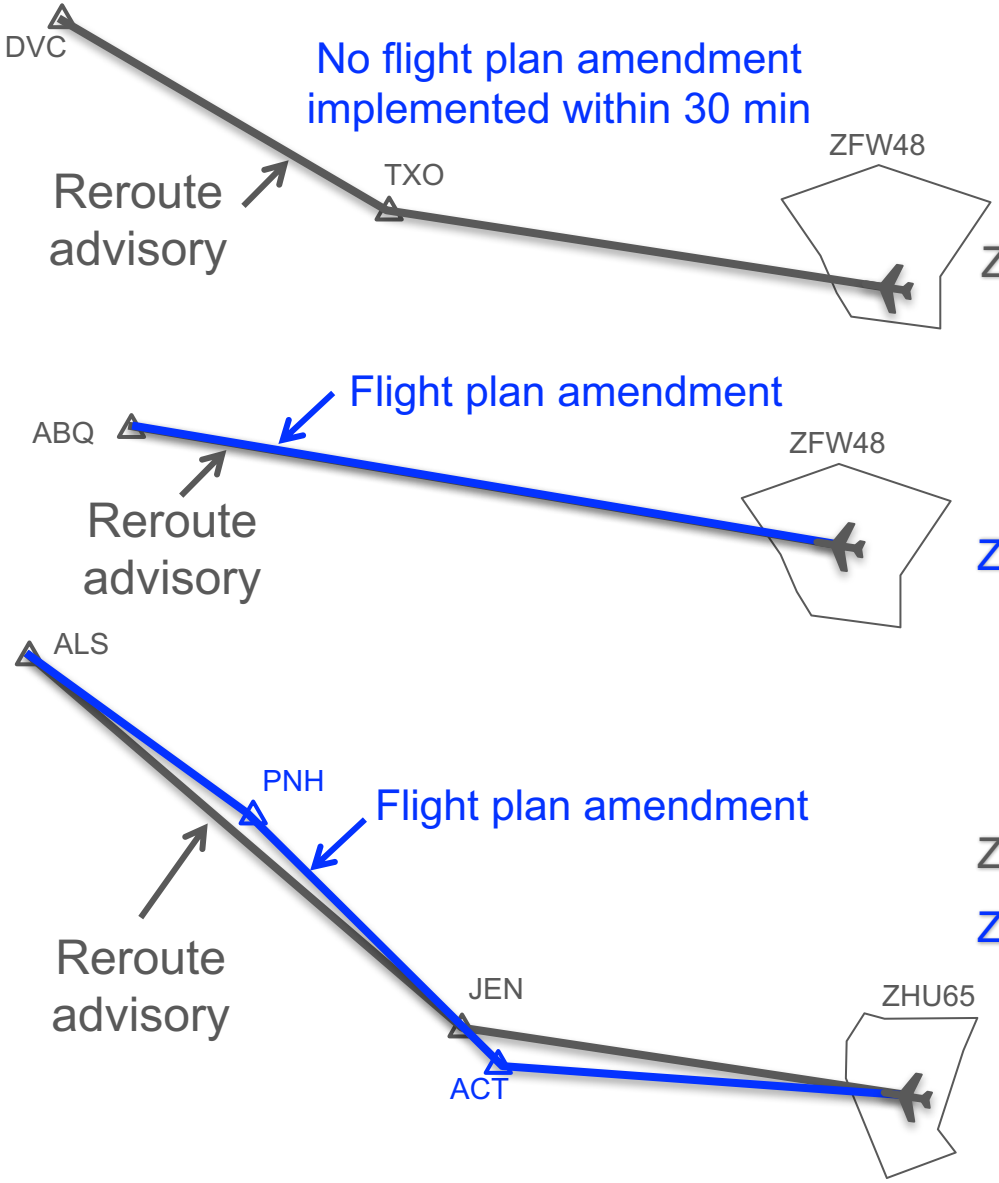


Future ATM Concepts Evaluation Tool (FACET)



Sector Counts etc.

Classifying Routings



ZFW48.TXO.DVC — ATC Rejected (9%)

ZFW48.ABQ — ATC Acceptable (13%)

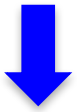
ZHU65.JEN.ALS — ATC Rejected (31%)

ZHU65.ACT.PNH.ALS — ATC Acceptable (47%)

Model Development

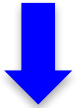
Feature Selection

- Forward search through 10 features



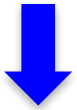
Model Selection

- Logistic regression
- Decision tree
- Support Vector Machine (SVM) with sigmoid kernel
- Random forest
- Adaptive Boost (AdaBoost)



Parameter Selection

- e.g., Number of trees

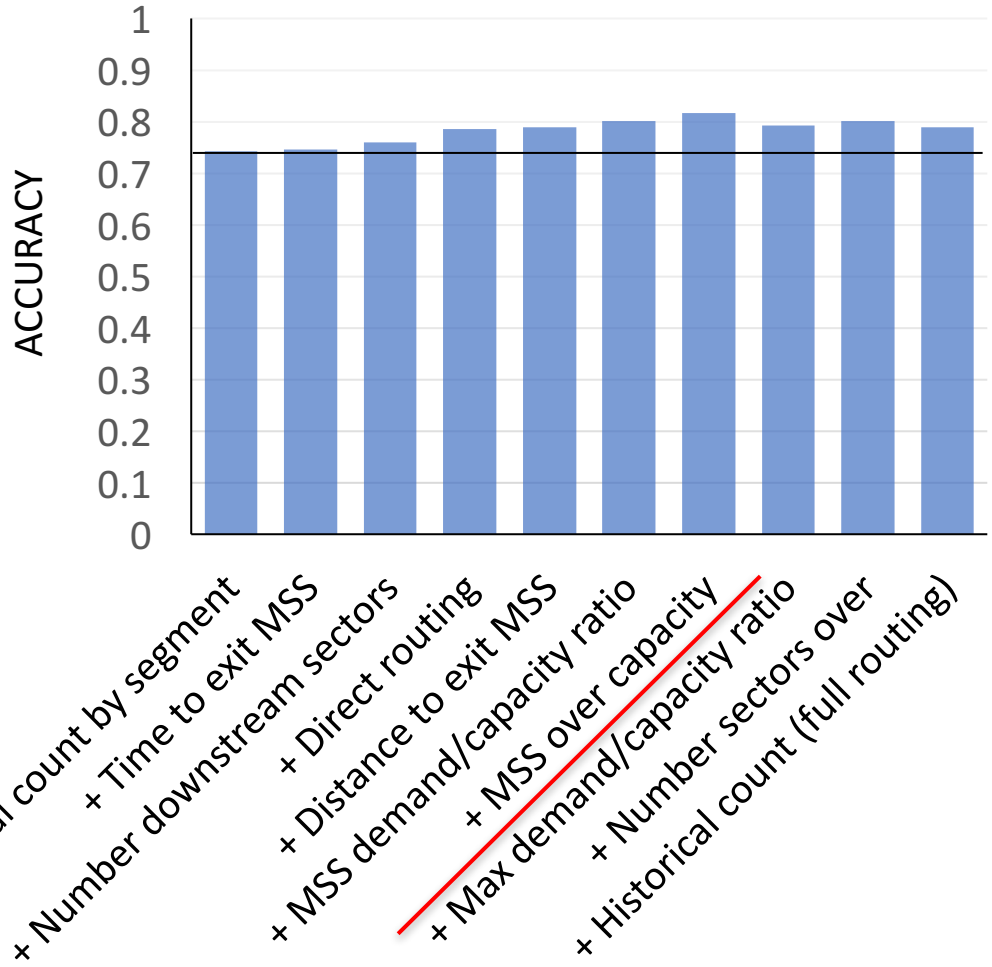


Model Validation

- Nested cross-validation

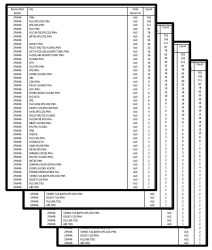
Feature Selection

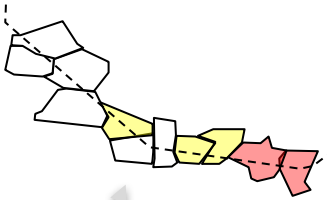
- Forward Search with Random Forest, 10-fold cross validation
- 317 to 544 observations – 40% to 48% Rejected; 60% to 52% Accepted



MSS – Maneuver Start Sector

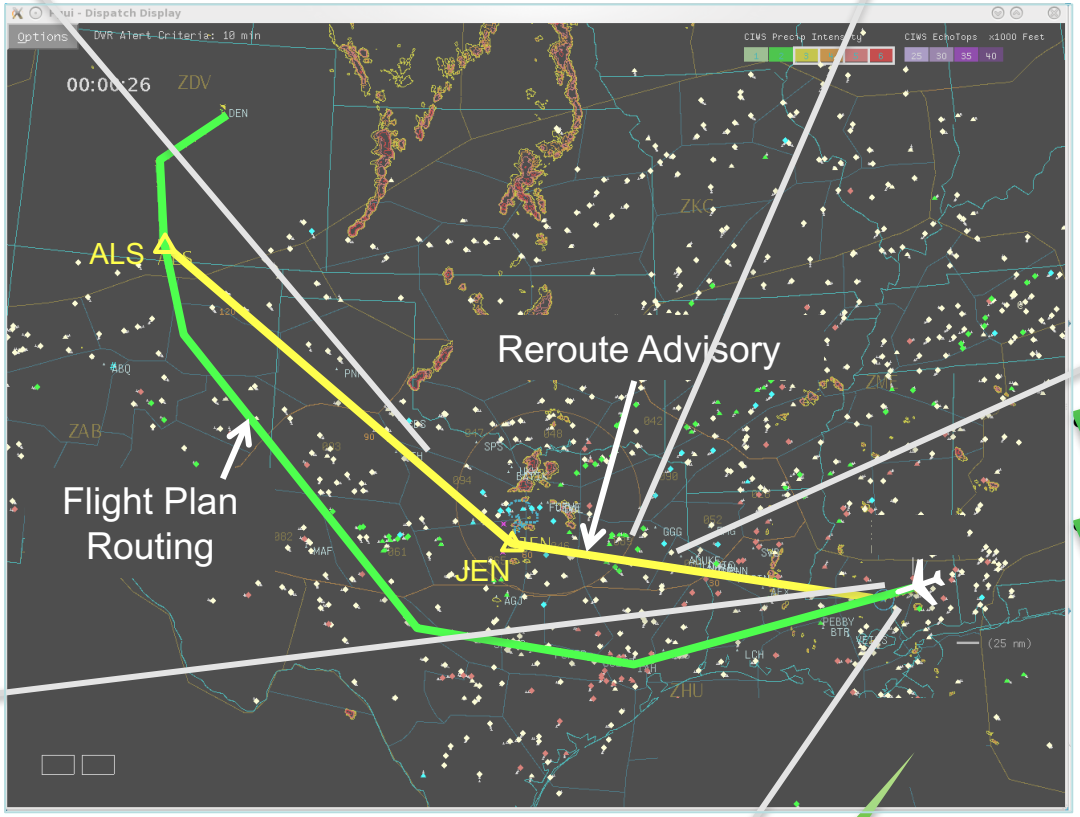
Features

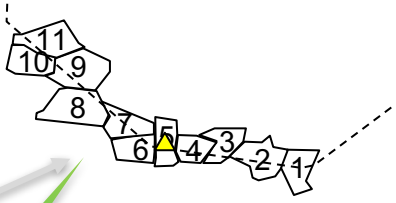




- Number sectors over capacity
- Max demand to capacity ratio

- Historical count (full route)
- Historical count (route segment)





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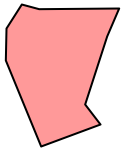
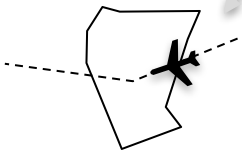


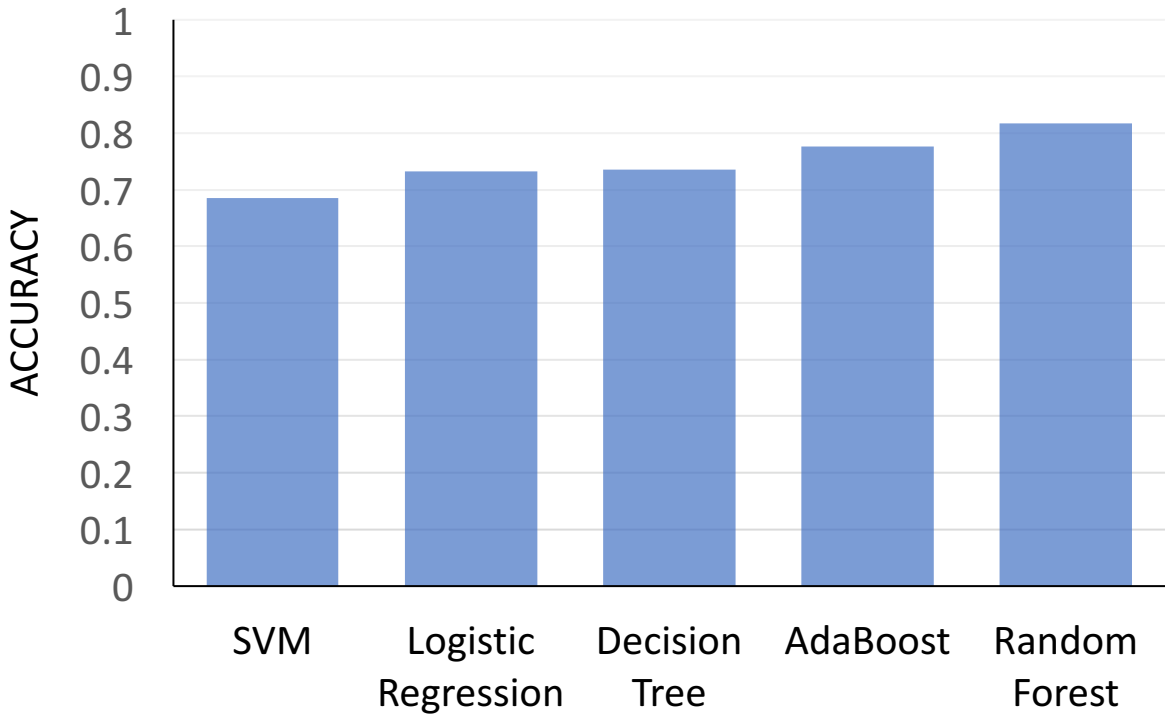
- Maneuver start sector demand/capacity
- Maneuver start sector over capacity



- Time to exit maneuver start sector
- Distance between maneuver start point and sector exit

Model Selection

- 7 features
- 10-fold cross validation
- 317 observations – 48% Rejected; 52% Accepted



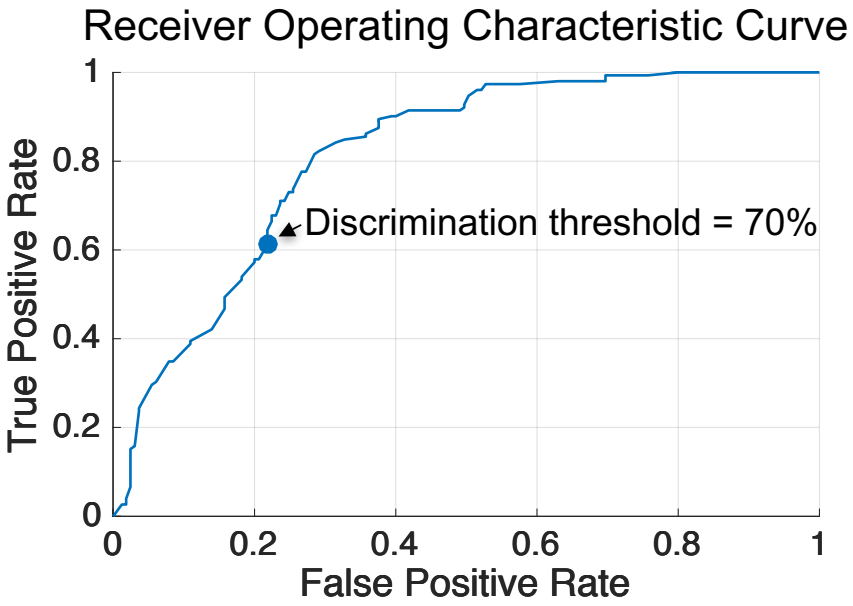
- Parameter Selection: 40 trees

Model Validation

- 7 features, Random Forest, 40 trees
- Nested 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

Observed (Actual) \ Predicted	Rejected	Accepted
Rejected	61%	39%
Accepted	22%	78%

Model Accuracy: 70%



Conclusions

- Developed a predictor of operational acceptability for route advisories:
  - Accuracy of 74%
  - Route rejection predicted at rate of 88%
- Relevant model features:
  - Historical usage
  - Timing/location of request in maneuver start sector
  - Number of downstream sectors
  - Direct routing or via auxiliary waypoints
  - Demand to capacity levels in maneuver start sector
- Best performing model is Random Forest with 40 trees

Future Work

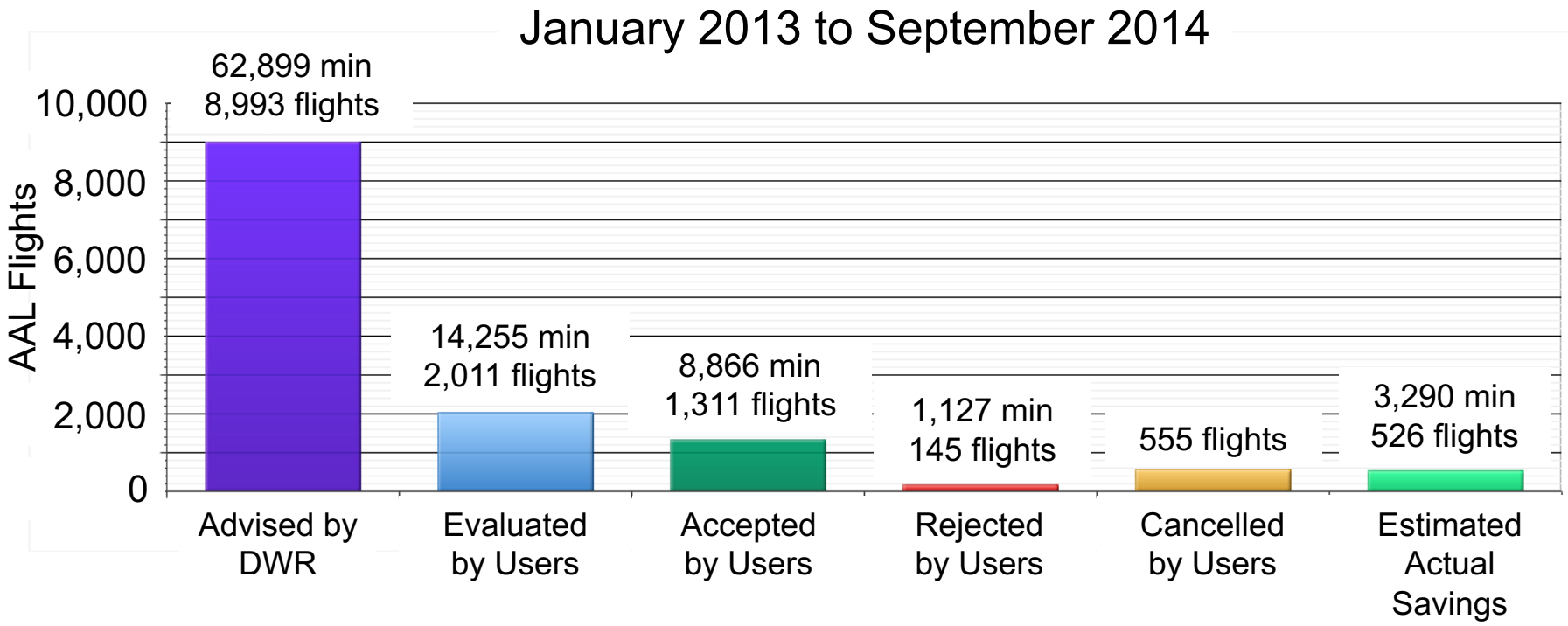
- Extension to other airspace
  - Trial data for NAS Constraint Evaluation and Notification Tool (NASCENT)

- Improve features
  - Include weather impact on maneuver start sector capacity
  - Add other features, e.g., Center information
  - May use voice recordings to identify timing and details of pilot requests to ATC

Questions?

Back-up Slides

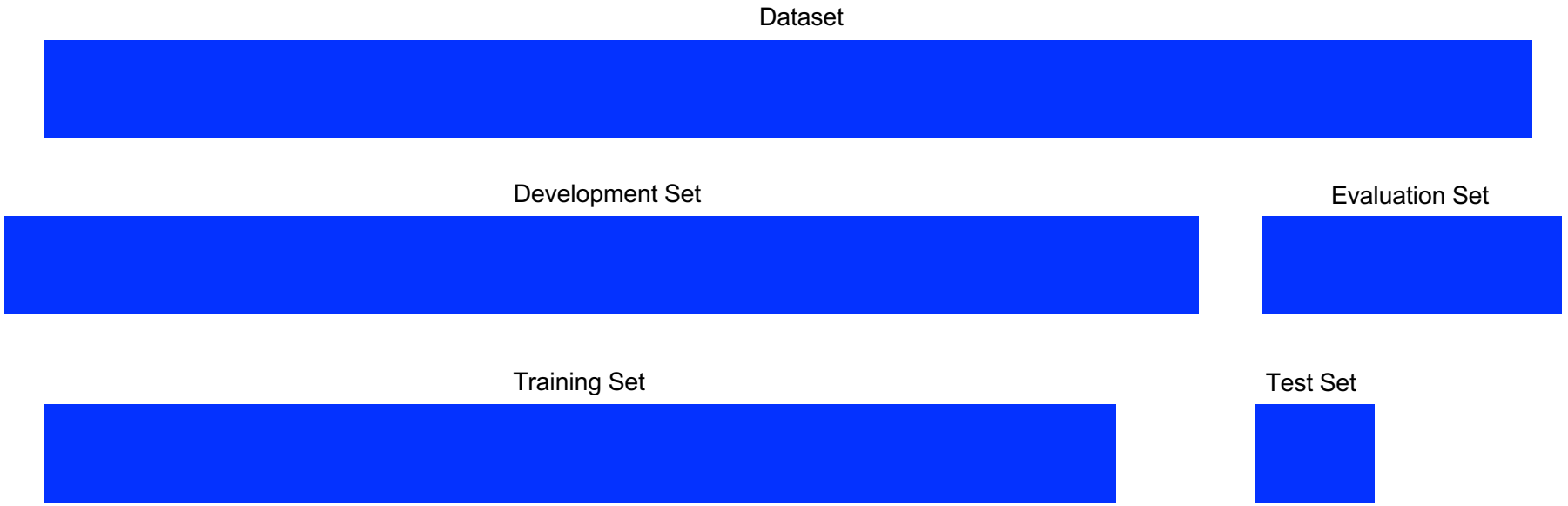
DWR Use and Estimated Actual Savings



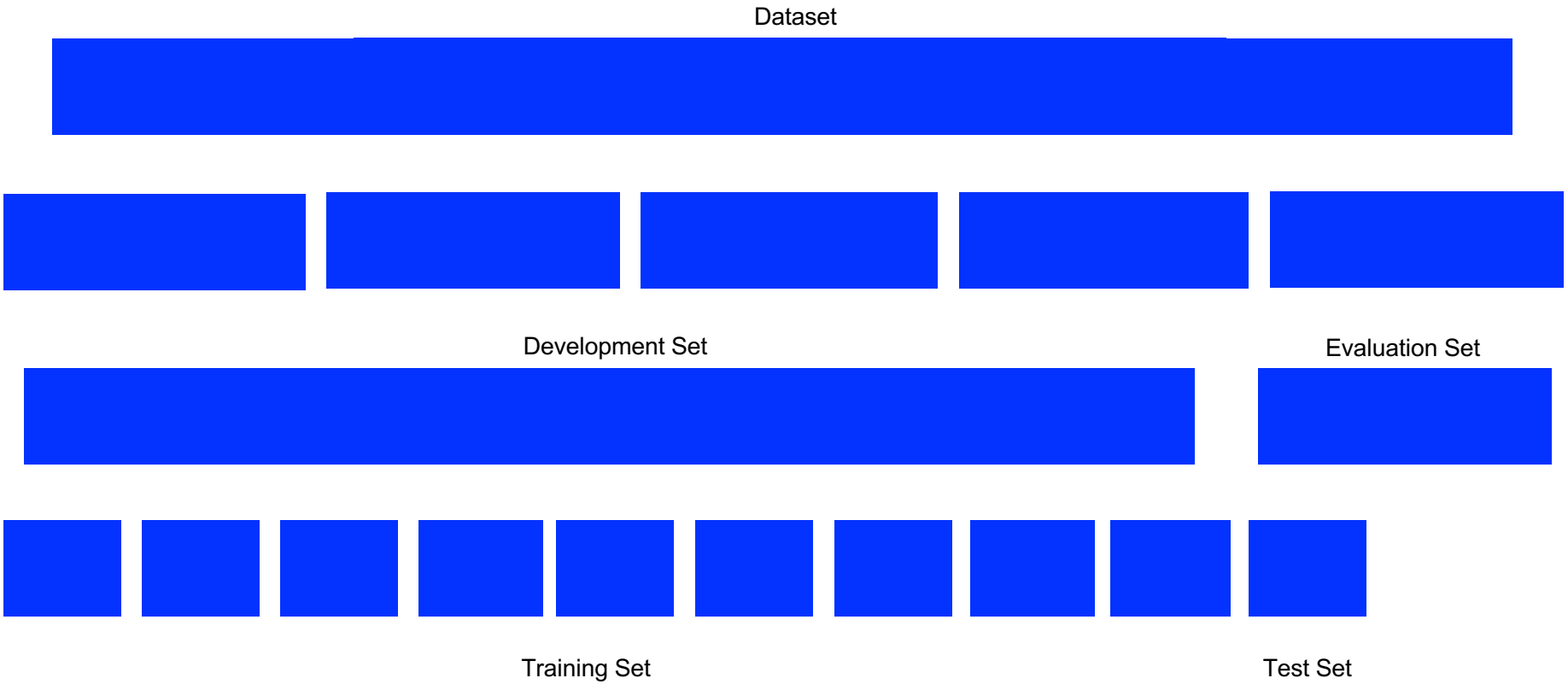
40% of dispatcher accepted routes see actual savings

McNally, D., Sheth, K., Gong, C., Sterenchuk, M., Sahlman, S., Hinton, S., Lee, C., Shih, F-T., "Dynamic Weather Routes: Two Years of Operational Testing at American Airlines," *Air Traffic Control Quarterly*, Vol. 23, No. 1, pp. 55-81, 2015.

Traditional Model Development

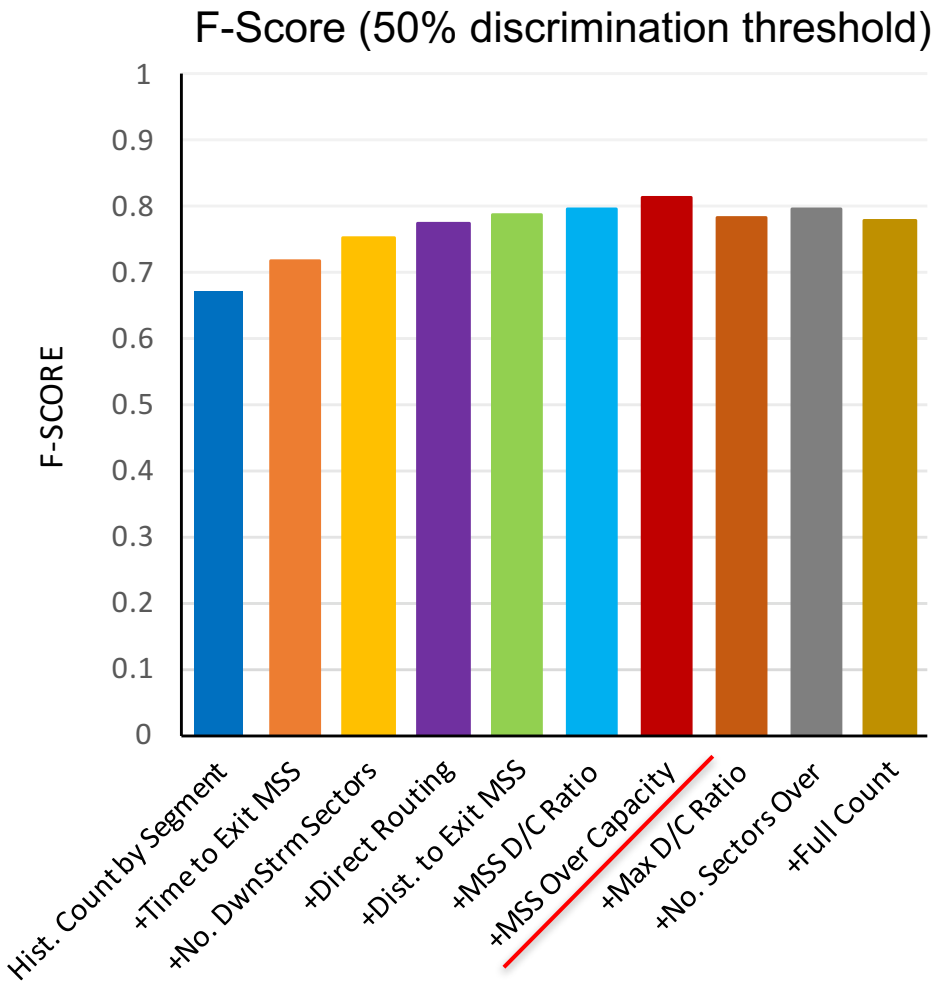


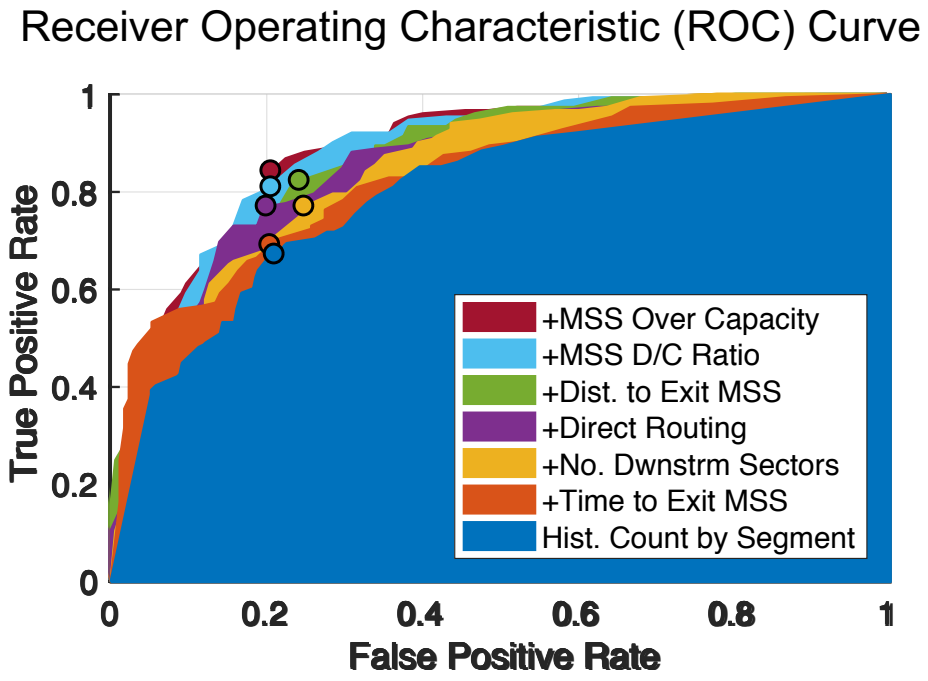
Nested Cross Validation



Feature Selection: Forward Search

- Random Forest, 10-fold cross validation
- 317 to 544 observations – 40% to 48% Rejected (positive); 60% to 52% Accepted (negative)





Feature Selection: Forward Search

- Method: Random Forest, 40 trees, 10-fold cross-validation
- Positive (Rejected or Modified) 40%; Negative (Accepted) 60%
- Observations: between 317 and 544, depending on features included

Model F-Score

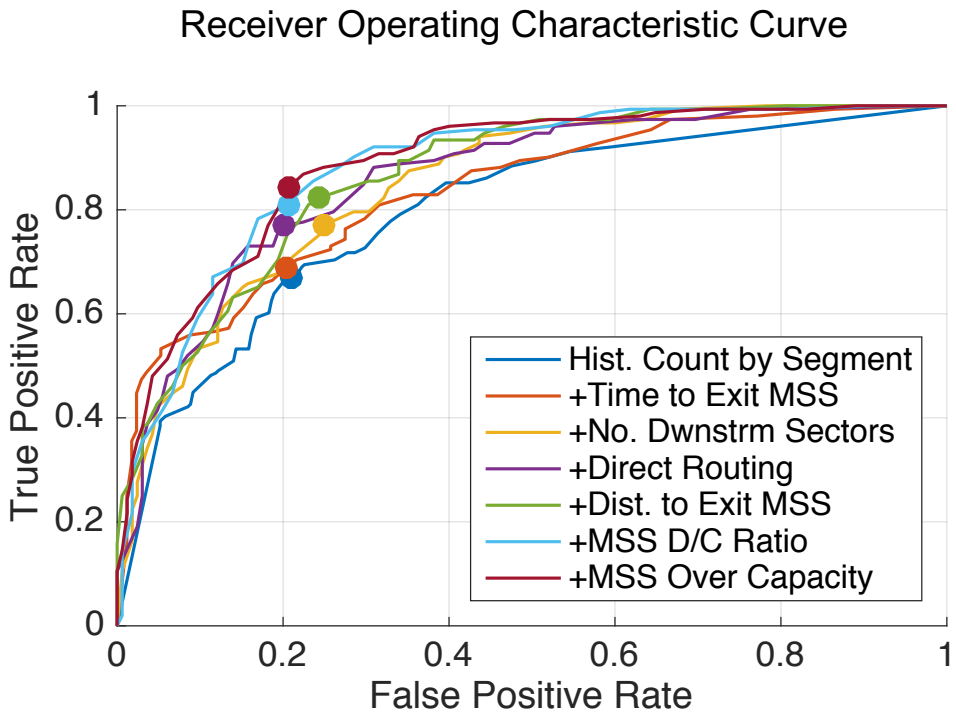
	1 Feature	2 Features*	3 Features*	4 Features*	5 Features*	6 Features*	7 Features*	8 Features*	9 Features*	10 Features*
Full Count	0.648	0.695	0.753	0.771	0.764	0.766	0.801	0.775	0.767	**0.780**
Concat. Count	**0.674**	-	-	-	-	-	-	-	-	-
Direct Routing	0.387	0.597	0.705	**0.775**	-	-	-	-	-	-
No. Sectors Over	NA	0.599	0.693	0.743	0.746	0.766	0.809	0.783	**0.797**	-
Max D/C Ratio	0.255	0.664	0.751	0.773	0.769	0.789	0.772	**0.784**	-	-
MSS Over Capacity	NA	0.583	0.674	0.744	0.758	0.782	**0.815**	-	-	-
MSS D/C Ratio	0.381	0.660	0.749	0.758	0.773	**0.796**	-	-	-	-
No. Dwnstrm. Sectors	0.484	0.667	**0.755**	-	-	-	-	-	-	-
Time to Exit MSS	0.497	**0.719**	-	-	-	-	-	-	-	-
Dist. to Exit MSS	0.467	0.665	0.719	0.761	**0.789**	-	-	-	-	-

* Includes feature set with highest F-Score from previous column

- Feature Set with highest F-Score:
  - Concatenation Count,
  - Number of Downstream Sectors,
  - Distance to Exit MSS,
  - MSS Over Capacity
  - Time to Exit MSS,
  - Direct Routing
  - MSS Demand/Capacity Ratio

Feature Selection

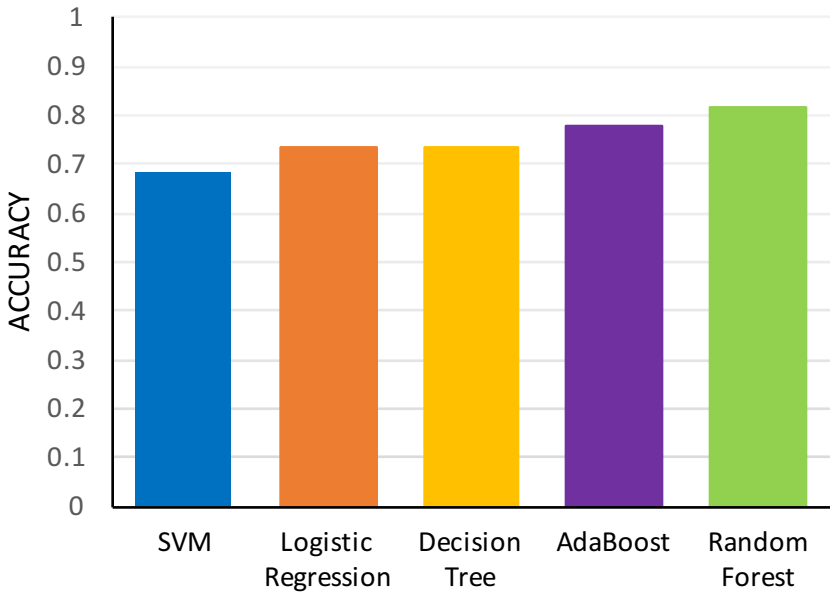
- Forward Search, using a Random Forest and 10-fold cross-validation
- Feature Set with highest F-Score:
  - Hist. Count by Segment,
  - Number of Downstream Sectors,
  - Distance to Exit Maneuver Start Sector,
  - Maneuver Start Sector Over Capacity.
  - Time to Exit Maneuver Start Sector,
  - Direct Routing,
  - Maneuver Start Sector Demand/Capacity Ratio,



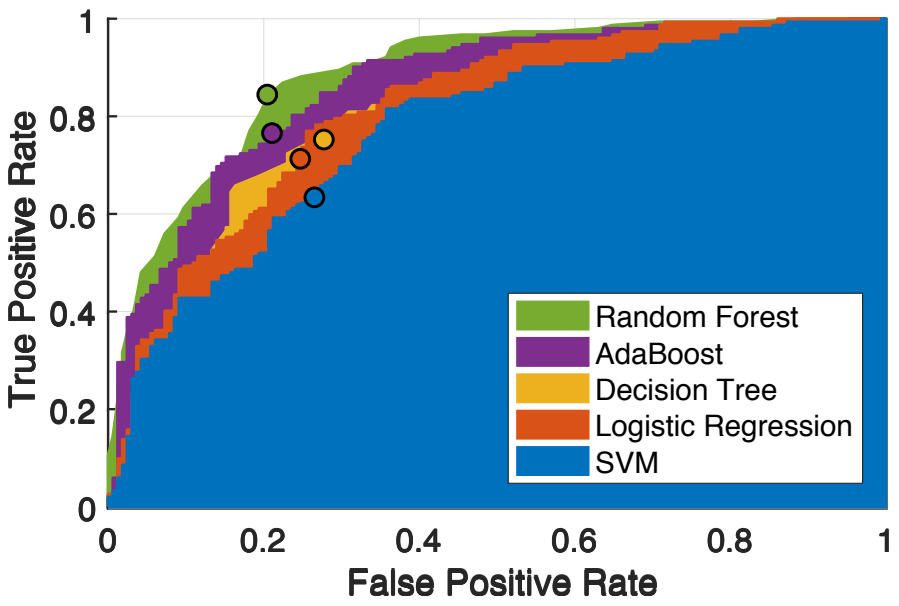
Model Selection

- 7 features
- 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

Accuracy (50% discrimination threshold)



Receiver Operating Characteristic (ROC) Curve

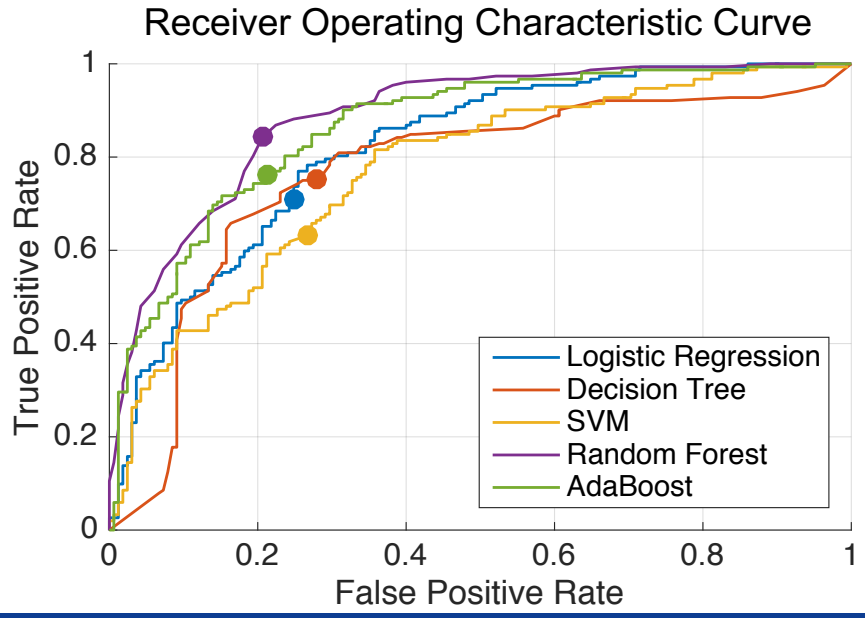


- Parameter Selection: 40 trees

Model Selection

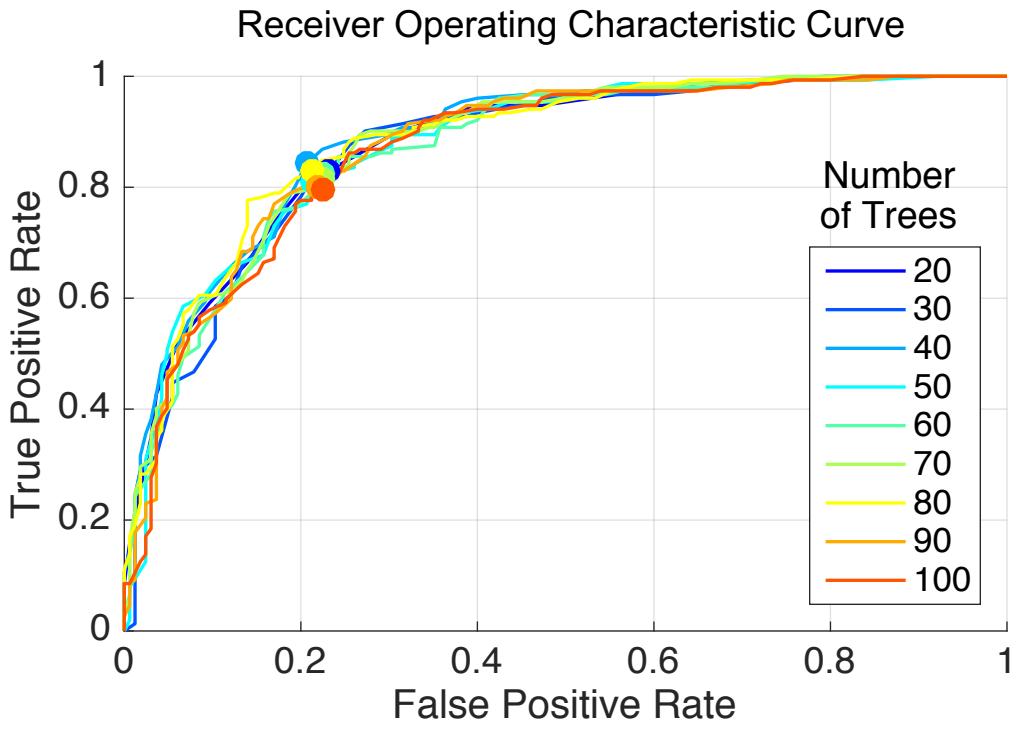
- 10-fold cross-validation
- 317 observations – 48% Positive (Rejected or Modified); 52% Negative (Accepted)

	Logistic Regression	Decision Tree	SVM	Random Forest	AdaBoost
Accuracy	0.73	0.74	0.69	0.82	0.78
Misclassification Error	0.27	0.26	0.31	0.18	0.22
True Positive Rate/Recall	0.71	0.75	0.63	0.84	0.76
True Negative Rate	0.75	0.72	0.73	0.79	0.79
Precision	0.73	0.71	0.69	0.79	0.77
F-score	**0.72**	**0.73**	**0.66**	**0.82**	**0.77**



Parameter Selection: Number of Weak Learners

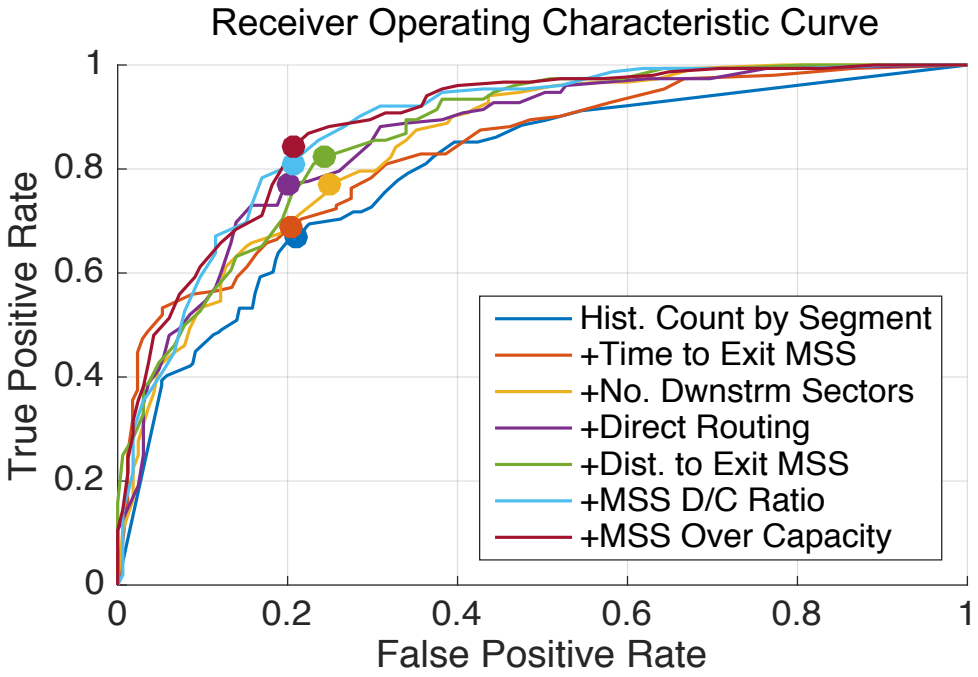
- Random Forest, with 10-fold cross validation
- 317 observations – 48% Positive (Rejected or Modified); 52% Negative (Accepted)
- Parameter value with highest F-Score: 40 trees



Feature Selection

- Method: Forward Search, training a Random Forest with 40 trees, using 10-fold cross-validation
- Metric: F-Score
- Observations: between 317 and 544, depending on features included
- Data Balancing: Positive (Rejected or Modified) 40%; Negative (Accepted) 60%

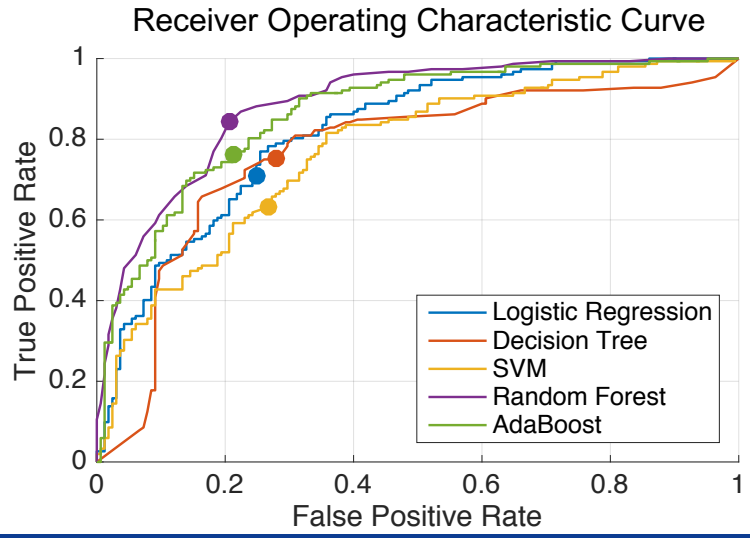
- Feature Set with highest F-Score (0.815):
  - Hist. Count by Segment,
  - Number of Downstream Sectors,
  - Distance to Exit MSS,
  - MSS Over Capacity
  - Time to Exit MSS,
  - Direct Routing
  - MSS Demand/Capacity Ratio



Model Selection

- Method: 10-fold cross-validation
- Observations: 317
- Data Balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- Features: Hist. Count by Segment, Time to Exit MSS, No. Downstream. Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.

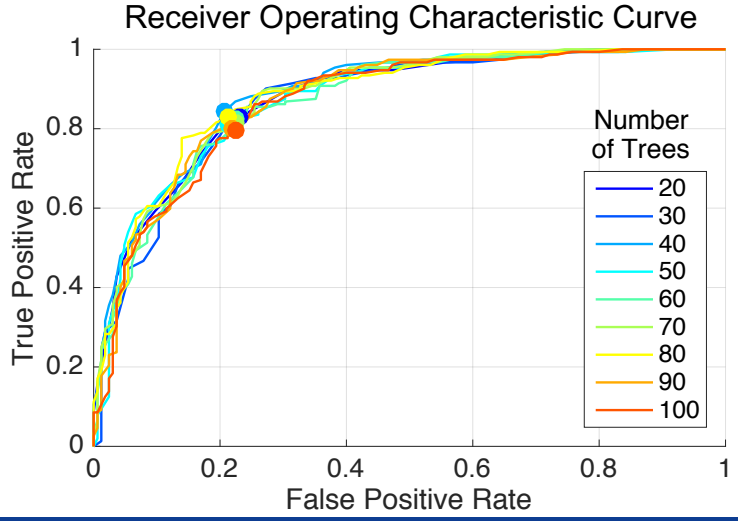
	Logistic Regression	Decision Tree	SVM	Random Forest	AdaBoost
Accuracy	0.732	0.735	0.685	0.817	0.776
Misclassification Error	0.268	0.265	0.315	0.183	0.224
True Positive Rate	0.711	0.750	0.632	0.842	0.763
True Negative Rate	0.752	0.721	0.733	0.794	0.788
Precision	0.725	0.713	0.686	0.790	0.768
F-score	**0.718**	**0.731**	**0.658**	**0.815**	**0.766**
Area Under ROC	0.818	0.767	0.770	0.886	0.864
Average Precision	0.776	0.687	0.735	0.870	0.826



Parameter Selection: Number of Weak Learners

- Method: Random Forest, with 10-fold cross validation — Metric: F-Score
- Data Balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52% — Observations: 317
- Features: Hist. Count By Segment, Time to Exit MSS, No. Dwnstrm. Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.

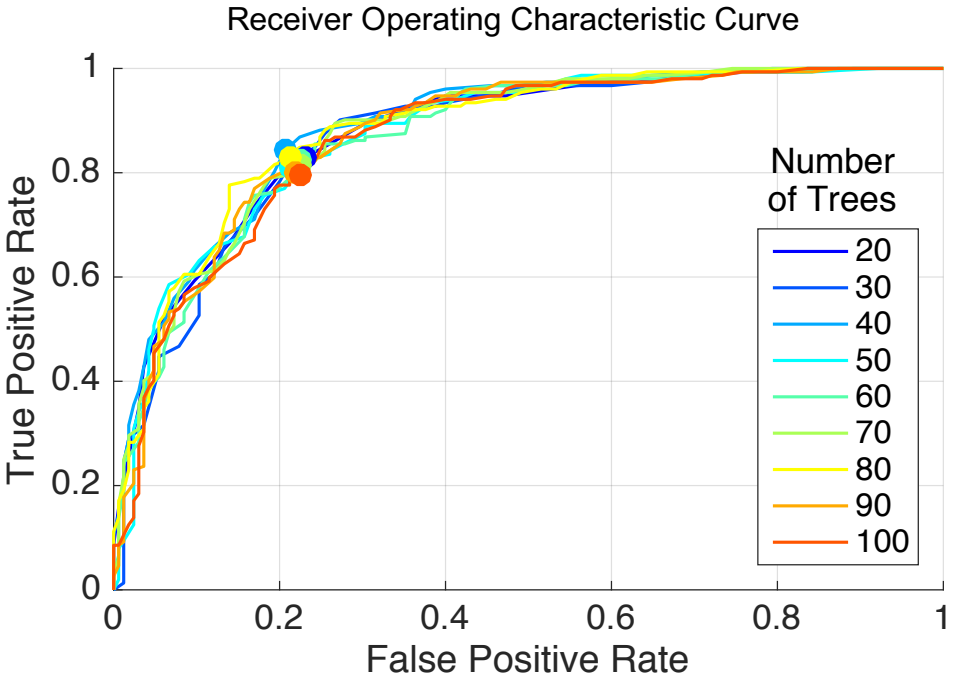
Number of Trees:	20	30	40	50	60	70	80	90	100
Accuracy	0.798	0.801	0.817	0.798	0.798	0.795	0.808	0.792	0.785
Misclassification Error	0.202	0.199	0.183	0.202	0.202	0.205	0.192	0.208	0.215
True Positive Rate	0.829	0.816	0.842	0.809	0.822	0.816	0.829	0.803	0.796
True Negative Rate	0.770	0.788	0.794	0.788	0.776	0.776	0.788	0.782	0.776
Precision	0.768	0.780	0.790	0.778	0.772	0.770	0.783	0.772	0.766
F-score	**0.797**	**0.797**	**0.815**	**0.794**	**0.796**	**0.792**	**0.805**	**0.787**	**0.781**
Area Under ROC	0.877	0.871	0.886	0.875	0.870	0.878	0.883	0.874	0.867
Average Precision	0.860	0.820	0.870	0.833	0.844	0.854	0.863	0.840	0.835



Parameter Selection: Number of Weak Learners

- Method: Random Forest, with 10-fold cross validation
- Metric: F-Score
- Observations: 317
- Data Balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- Features: Hist. Count by Segment, Time to Exit MSS, No. Downstream Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.

- Parameter value with highest F-Score (0.815):
  - 40 trees

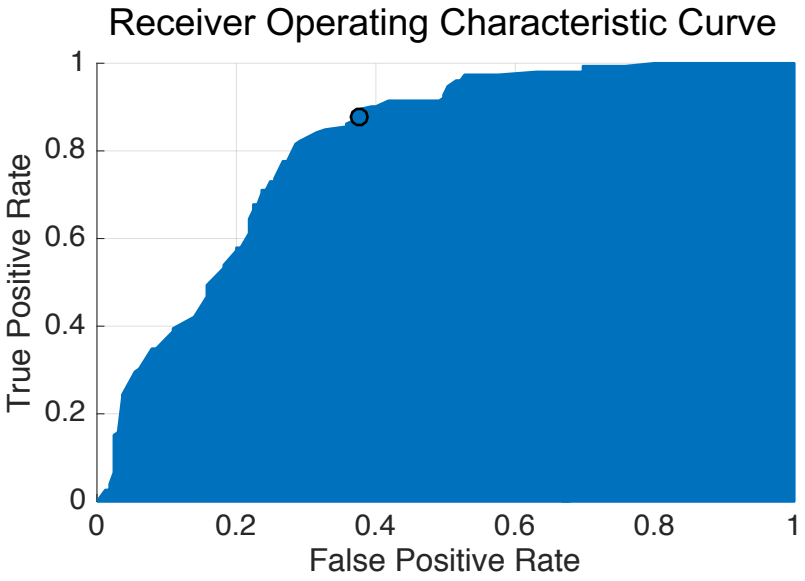


Model Validation

- Random Forest, 7 features, 40 trees
- Nested 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

		Predicted	
		Rejected	Accepted
Observed (Actual)	Rejected	88%	12%
	Accepted	38%	62%

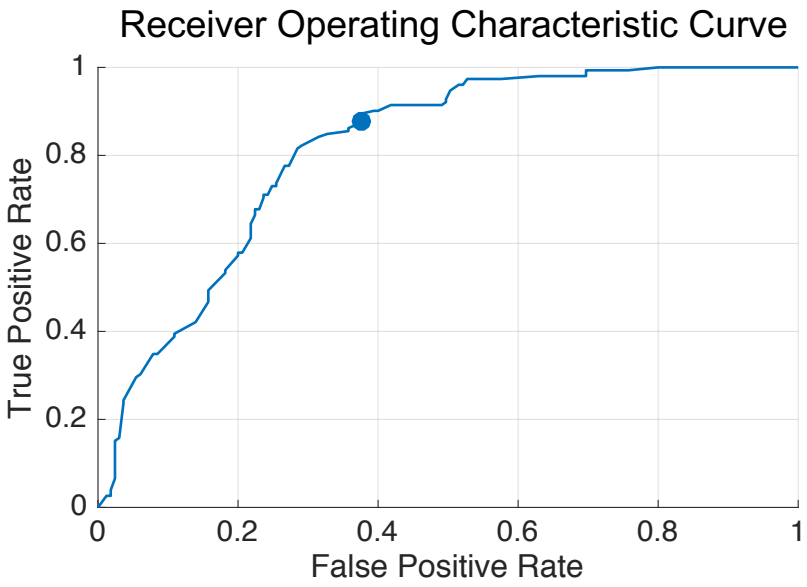
Model Accuracy: 74%



Model Validation

- Method: Random Forest, with 10-fold nested cross validation
- Observations: 317
- Data Balancing: Positive (Rejected or Modified) 40%; Negative (Accepted) 60%

	Nested Cross-Validation
Accuracy	0.744
Misclassification Error	0.256
True Positive Rate/Recall	0.875
True Negative Rate	0.624
Precision	0.682
FScore	**0.767**
Area Under ROC	0.814
Average Precision	0.742



Comparison to One-Class Classification

- Method: 10-fold cross-validation
- Observations: 317
- Data balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- Features: Hist. Count by Segment, Time to Exit MSS, No. Downstream Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Capacity

	Random Forest	Two-Class SVM	One-Class SVM
Accuracy	0.817	0.685	0.558
Misclassification Error	0.183	0.315	0.442
True Positive Rate/Recall	0.842	0.632	0.211
True Negative Rate	0.794	0.733	0.879
Precision	0.790	0.686	0.615
FScore	**0.815**	**0.658**	**0.314**